NEURO-OSTEOARTHROPATHY

THE CHARCOT FOOT

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CLASSIFICATION OF NEURO-OSTEOARTHROPATHY

Neuro-osteoarthropathy (Charcot arthropathy, Charcot osteoarthropathy, neuropathic osteoarthropathy) represents one of the most serious complications of diabetes. Its prevalence is between 1 and 7.5%; bilateral involvement has been reported to occur in 6–40% of patients in several series. The development of this complication depends on peripheral somatic and autonomic neuropathy, together with adequate blood supply to the foot. A minor trauma, often unrecognized by the patient, may initiate the process of joint and bone destruction. Some cases of neuro-osteoarthropathy have been reported after infection of the foot, surgery to the ipsilateral or the contralateral foot, or restoration of foot circulation. Mean age of presentation is approximately 60 years and the majority of the patients have diabetes of more than 15 years' duration. Men and women are affected equally.

CLASSIFICATION OF NEURO-OSTEOARTHROPATHY, BASED ON CHARACTERISTIC ANATOMIC PATTERNS OF BONE AND JOINT DESTRUCTION

Classification Proposed by Sanders and Frykberg (1991)

Pattern I: Forefoot (involvement of interphalangeal joints, phalanges, metatarsophalangeal joints, distal metatarsal bones). The frequency of this pattern is 26–67%, and it is often associated with ulceration over the metatarsal heads.

Pattern II: Tarsometatarsal joints. The frequency of this pattern is 15–48%; it often causes collapse of the midfoot and a rocker-bottom foot deformity.

Pattern III: Naviculocuneiform, talonavicular and calcaneocuboid joints. The frequency of this pattern is 32%; it often causes collapse of the midfoot and a rocker bottom foot deformity, particularly when it is combined with pattern II.

Pattern IV: Ankle and subtalar joints. Although this pattern accounts for only 3–10% of the cases of neuro-osteoarthropathy, it invariably causes severe structural deformity and functional instability of the ankle.

Pattern V: Calcaneus. Avulsion fracture of the posterior tubercle of the calcaneus. This pattern is not in fact neuro-osteoarthropathy, since no joint involvement occurs. This pattern is rare.

Classification Proposed by Dounis (1997)

According to the classification proposed by Dounis in 1997, there are three main types of neuro-osteoarthropathy (Figure 9.1):

Type I: This type is similar to pattern I as in the above classification proposed by Sanders and Frykberg, and involves the forefoot.

Type II: Type II involves the midfoot (tarsometatarsal, naviculocuneiform, talonavicular and calcaneocuboid joints); its main consequence is the collapse of the midfoot and development of rocker-bottom foot deformity.

Type III: Type III involves the rearfoot and is subclassified as:

IIIa (ankle joint): Main consequence is instability.

IIIb (subtalar joint): Main consequence is instability and development of varus deformity of the foot.

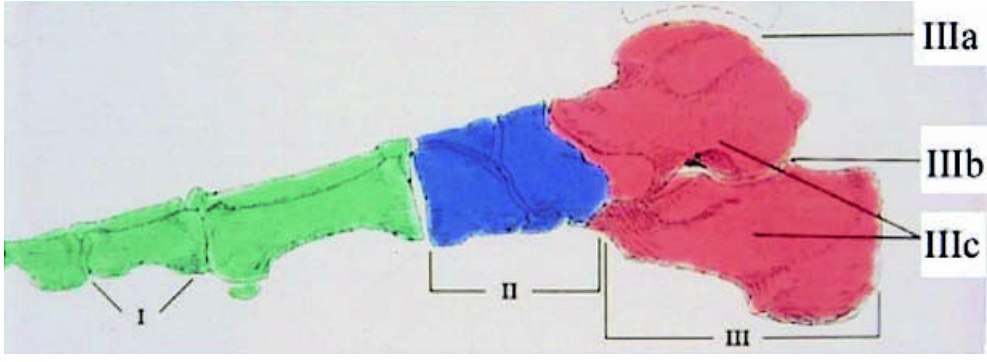

Figure 9.1 Dounis classification of neuro-osteoarthropathy. Refer to text

IIIc (resorption of talus and/or calcaneus): This type is associated with the inability to bear weight.

The IIIc subcategory is similar to pattern V as proposed by Sanders and Frykberg, but it includes some cases with resorption either of the talus or the calcaneus or both bones. The classification proposed by Dounis is less complex than that suggested by Sanders and Frykberg as it is based on the three anatomic areas of the foot.

Other classifications have been also described (Harris and Brand, 1966; Lennox, 1974; Horibe *et al.*, 1988; Barjon, 1993; Brodsky and Rouse, 1993; Johnson, 1995). Detailed descriptions of these classification systems can be found in the literature.

CLINICAL PRESENTATION AND LABORATORY FINDINGS

A typical clinical presentation is a patient with a swollen, warm and red foot with mild pain or discomfort. Usually there is a difference in skin temperature of more than 2 °C compared to the unaffected foot. Most patients do not report any trauma, although some may recall a minor injury such as a mild ankle sprain. On examination, pedal pulses are bounding and findings of peripheral neuropathy are constantly present. The white blood cell count is normal and the erythrocyte sedimentation rate may be slightly increased (20–40 mm/h).

RADIOLOGICAL FINDINGS

Radiological findings depend on the stage of the disease. Eichenholtz (1966) described three clinico-radiologically distinct stages. (a) The development stage, characterized by soft tissue swelling, hydrarthrosis, subluxations, cartilage debris (detritus), erosion of the cartilage and subchondral bone, diffuse osteopenia, thinning of the joint space and bone fragmentation. (b) The *coalescence* stage, characterized by evidence of restoration of the tissue damage: inflammation subsides, fine debris is absorbed, periosteal bone is formed, bone fragments fuse to the adjacent bones and the affected joints are stabilized. (c) The *reconstructive* stage, characterized by subchondral osteosclerosis, periarticular spurring, intra-articular and marginal exuberant osteophytes and ossification of ligaments and joint cartilage. Joint mobility is reduced and fusion and rounding of large bone fragments may be seen (Onvlee, 1998).

DIFFERENTIAL DIAGNOSIS

Diagnosis of acute neuro-osteoarthropathy requires a high level of vigilance for the disease. The acute development of foot swelling in a patient with long-standing diabetes and peripheral neuropathy is a clue to the presence of acute neuro-osteoarthropathy. In the early stages, plain radiographs may be normal and serial radiographic examination of the affected foot may be warranted. Acute infections (osteomyelitis, cellulitis) and crystal deposition disease should be excluded. Exclusion of osteomyelitis in such patients is not always easy. Scintigraphy studies and magnetic resonance imaging or computed tomography may not distinguish neuro-osteoarthropathy from osteomyelitis (Shaw and Boulton, 1995).

Keywords: Classification of neuro-osteoarthropathy; Charcot foot; Sanders and Frykberg classification; Dounis classification; clinical presentation of neuro-osteoarthropathy; radiological findings of neuro-osteoarthropathy; differential diagnosis of neuro-osteoarthropathy; Eichenholtz stage of neuro-osteoarthropathy

ACUTE NEURO-OSTEOARTHROPATHY: SANDERS AND FRYKBERG PATTERN I; DOUNIS TYPE I

A 56-year-old female patient with type 2 diabetes mellitus diagnosed at the age of 43 years and treated with sulfonylureas, was referred to the outpatient diabetic foot clinic for a forefoot ulcer and possible osteomyelitis. Diabetes control was acceptable (HBA_{1c}: 7.6%). She had background diabetic retinopathy and hypertension. On examination the forefoot was red, swollen, warm and painful; she had severe peripheral neuropathy and a clear ulcer under her right fifth metatarsal head of 2 weeks' duration; peripheral pulses on both feet were normal. The patient denied any trauma. An anteroposterior radiograph showed osteolytic destruction of her third and fourth metatarsal heads, widening of the third metatarsophalangeal joints and subluxation of the second metatarsophalangeal joint (Figure 9.2). The white blood cell count (WBC) was within the normal range and the erythrocyte sedimentation rate (ESR) was 25 mm/h. The patient was diagnosed as a case of acute neuro-osteoarthropathy and, after debridement of the ulcer, a total-contact cast was fitted and bed rest was advised. She had her cast changed on a weekly basis for 1 month and every 2 weeks thereafter for two more months. The ulcer healed completely in 4 weeks and she had a good recovery. Plain radiographs followed 2 weeks later in order to exclude osteomyelitis, but no further bone destruction was seen.

This type of bone destruction is quite similar to that seen in osteomyelitis. However, in this patient osteomyelitis was less possible due to the short duration of the ulcer and lack of infection which must be present to cause extensive bone destruction. Bone destruction due to osteomyelitis takes at least 2 weeks to become visible on plain radiographs. Involvement of bones and joints is typical in acute neuro-osteoarthropathy. An increase in the ESR (greater than 70 mm/h) and WBC is a common feature of acute osteomyelitis. Mild elevation of the ESR (usually less than 40 mm/h) is common in acute neuro-osteoarthropathy.

Other roentgenographic findings in pattern I neuro-osteoarthropathy include concentric resorption of phalanges and

Figure 9.2 Radiograph of acute neuro-osteoarthropathy showing osteolytic destruction of the third and fourth metatarsal heads, widening of the third metatarsophalangeal joint and subluxation of the second metatarsophalangeal joint

broadening of the bases of proximal phalanges with formation of a cup around the metatarsal heads. Osteolytic destruction of the metatarsophalangeal joints with a pencil-like tapering of the metatarsal shafts, epiphyseal absorption, thinning of the joint space and subluxation of the metatarsophalangeal and the phalangophalangeal joints,

Figure 9.3 Neuro-osteoarthropathy: concentric resorption of the phalanges of the three lesser toes, osteolytic destruction of the metatarsophalangeal joints and severe epiphyseal absorption are evident

may also be seen (Figure 9.3 exemplified by another patient). Pattern I-type neuro-osteoarthropathy is often complicated by plantar ulceration.

Keywords: Acute neuro-osteoarthropathy; plantar ulceration

DIFFERENTIAL DIAGNOSIS BETWEEN ACUTE TYPE I NEURO-OSTEOARTHROPATHY AND ACUTE OSTEOMYELITIS

A 62-year-old lady with type 2 diabetes diagnosed at the age of 48 years was referred to the outpatient diabetic foot clinic for possible acute osteomyelitis of her right foot. The patient had had a first ray amputation on the right side due to osteomyelitis 2 years earlier. Eventually second and third claw toe deformity developed and a chronic ulcer formed at the tip of her right second toe due to repeated trauma (Figure 9.4). During the previous 6 months the patient had been the subject of several scintigraphic studies which suggested osteomyelitis of her right second and third metatarsals, she had therefore been treated with ciprofloxacin and clindamycin.

On examination, claw toe deformity was observed; the dorsum of her right forefoot was red, swollen, painful and warm; she had severe peripheral neuropathy and bounding feet pulses. A clear non-infected

Figure 9.4 Right first ray amputation. Medial displacement and an ulcer on the tip of the second toe due to repeated trauma of the clawed toe can be seen

Figure 9.5 Radiograph of acute neuro-osteoarthropathy as shown in the patient whose foot is illustrated in Figure 9.4. Osteolytic destruction of the second and third metatarsal heads, widening of the third metatarsophalangeal joint and subluxation of the second metatarsophalangeal joint are evident

ulcer was seen at the tip of her second toe. A plain radiograph (Figure 9.5) showed disintegration of her right second and third metatarsal heads and an avulsion fracture between her second and third proximal phalanges. Her white blood cell count (WBC) was 14,500, the erythrocyte sedimentation rate (ESR) was 104 mm/h and the C-reactive protein level was 45 mg/dl. The patient's foot was immobilized by the use of a total-contact cast and she continued with antibiotics as the probability of osteomyelitis was high. She continued using the cast and the antibiotic treatment for 3 months. At that time the WBC was normal and the ESR and C-reactive protein levels were mildly elevated. One year later, a plain radiograph (Figure 9.6) revealed broadening of her second metatarsal head, proliferative changes of her third metatarsal head and lateral exostosis of the proximal phalanx of her second toe. These findings correspond to the *reconstructive* stage in the evolution of neuro-osteoarthropathy.

Differential diagnosis in this case included osteomyelitis and acute neuro-osteoarthropathy. Scintigraphy and hematology studies suggested the presence of osteomyelitis. Radiographic findings are similar in both acute Charcot foot and osteomyelitis (see Figure 8.37 which shows scintigraphy studies of the same patient). It is also possible that both conditions coexisted for some time, as an acute infection may initiate acute neuro-osteoarthropathy. Whatever was the case, the patient had a good outcome and no further foot deformity developed.

Figure 9.6 X-ray showing the progression of neuro-osteoarthropathy in the patient whose foot is illustrated in Figures 9.4 and 9.5. This radiograph was taken 1 year after that shown in Figure 9.4. Broadening of the second metatarsal head, proliferative changes of the third metatarsal head and lateral exostosis of the proximal phalanx of the second toe are all evident

Keywords: Acute neuro-osteoarthropathy; type I neuro-osteoarthropathy; acute osteomyelitis

NEURO-OSTEOARTHROPATHY: SANDERS AND FRYKBERG PATTERNS II AND III; DOUNIS TYPE II: INVOLVEMENT OF THE FIFTH METATARSAL HEAD

A 40-year-old male patient with type 1 diabetes diagnosed at the age of 18 years was referred to the outpatient orthopedic department of our hospital for acute osteomyelitis in his left foot. The patient had fair diabetes control (HBA_{1c}: 7.2%) and background diabetic retinopathy.

On examination, redness, edema and warmth were noted on the dorsolateral aspect of his left foot (Figure 9.7), but no ulceration. A large ecchymosis was seen below the external malleolus, but the patient denied any trauma. He had diabetic neuropathy with severe loss of sensation of pain, light touch and temperature perception, but he could feel vibration. The vibration perception threshold was 10 V in both feet. The difference in temperature between the two feet was 3.5 °C. Peripheral pulses

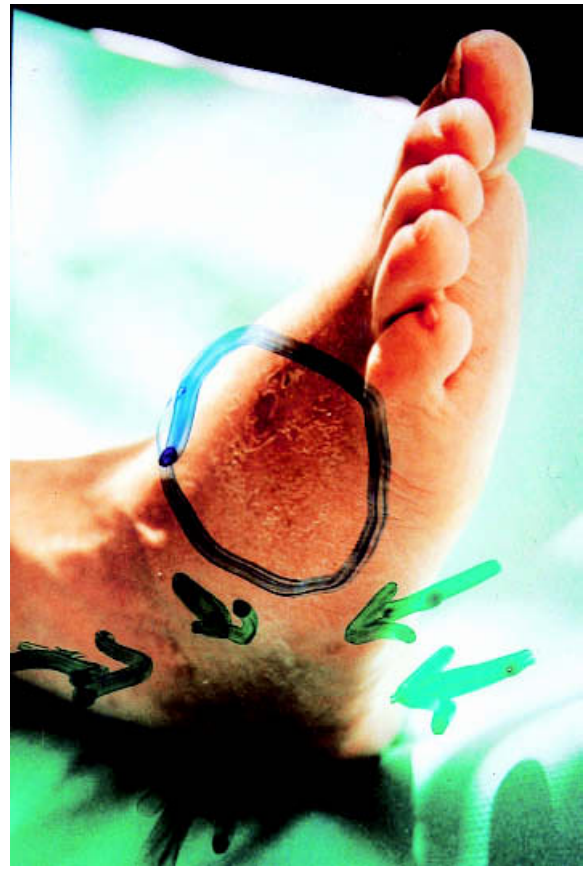

Figure 9.7 Redness and edema on the dorsolateral aspect of this foot is due to acute neuro-osteoarthropathy. A large ecchymosis below the external malleolus is due to an avulsion fracture of the base of the fifth metatarsal

were palpable and the ankle brachial index was 1.2 bilaterally.

An anteroposterior radiograph showed an avulsion fracture of the tubercle of his left fifth metatarsal base together with mild erosion of his left cuboid bone (Figure 9.8). Acute neuro-osteoarthropathy was diagnosed; a total-contact cast was applied and the patient was advised to limit his activity to a minimal level. He had the cast changed on a weekly basis initially and every 2 weeks thereafter for 3 months. He had a good recovery with minimal foot deformity.

Figure 9.8 Radiograph of acute neuro-osteoarthropathy in the patient whose foot is shown in Figure 9.7. An avulsion fracture of the tubercle of the left fifth metatarsal base, together with mild erosion of the left cuboid bone can be seen

This patient had preserved function of the large myelinated fibers as evidenced by normal sensation of vibration as well as the vibration perception thresholds, and damage to the small nerve fibers responsible for sensations of pain, light touch and temperature. The pattern of nerve fiber damage may vary considerably in diabetes. The most common pattern is impairment of all nerve fibers; however, damage of the large myelinated fibers with preservation of the small unmyelinated fibers and vice versa may also be seen.

Pattern II (or Dounis' type II) is the commonest pattern of neuro-osteoarthropathy, characterized by involvement of the tarsometatarsal joints (Lisfranc's joint). Osteolytic destruction at this site may result in collapse of cuneiforms and/or cuboid bone and a rocker-bottom foot deformity. Ulcers may develop at the apex of collapsed bones.

The patient's ecchymosis was probably due to an avulsion fracture of the base of his fifth metatarsal bone.

Keywords: Pattern II neuro-osteoarthropathy; fracture; cuboid bone; fifth metatarsal

NEURO-OSTEOARTHROPATHY: SANDERS AND FRYKBERG PATTERNS II AND III; DOUNIS TYPE II: PARTIAL RESORPTION OF LISFRANC'S JOINT

A 38-year-old lady with type 1 diabetes diagnosed at the age of 19 years attended the outpatient diabetic foot clinic because of mild discomfort in her right midfoot.

Symptoms persisted for 1 week and the patient denied any trauma.

On examination, the right midfoot was red and swollen. She had claw toe deformity, and a small superficial neuropathic ulcer on the dorsum of the second right toe (Figure 9.9). Peripheral pulses were normal. Severe peripheral neuropathy was found with loss of sensation of light touch, pain, temperature and vibration. She could not feel 5.07 monofilaments. The vibration perception threshold was 40 V at the tip of the halluxes. A plain radiograph (Figure 9.10) revealed a partial disruption of the Lisfranc's joint with mild subluxation of the second metatarsal bone and mild lateral displacement of the last three metatarsals. Diagnosis of acute neuro-osteoarthropathy was made; a total-contact cast was fitted and 3 months later a prefabricated walker was fitted and used for a further 6 months (Figure 9.11). The outcome was good and no significant foot deformity developed.

Minimal second metatarsal dislocation may be easily overlooked in patients with mild symptoms. This type of neuro-osteoarthropathy should be diagnosed and managed early as it invariably results in collapse of the midfoot. A minimal (of a few millimeters) lateral deviation or a fracture of the base of the second metatarsal may be an early sign of acute neuro-osteoarthropathy. If the foot is not immobilized, dislocation of all metatarsals develops. Lateral displacement of the metatarsal bases on the cuneiform and cuboid bones occurs and eventually the midfoot collapses.

Prefabricated walkers are suitable alternatives to a total-contact cast, although they do not provide total contact. Application of inflatable pads improves contact. They are indicated in patients with impaired vascular circulation or in patients who require

Figure 9.9 Claw toe deformity and a small superficial neuropathic ulcer on the dorsum of the second right toe. No other apparent foot deformity is visible in this patient with early acute neuro-osteoarthropathy

Figure 9.10 Radiograph of acute neuro-osteoarthropathy in the patient whose foot is shown in Figure 9.9. Partial disruption of the Lisfranc's joint with mild subluxation of the second metatarsal bone and mild lateral displacement of the last three metatarsals can be seen

Figure 9.11 Prefabricated walker for the patient whose foot is illustrated in Figures 9.9 and 9.10. Prefabricated walkers are suitable alternatives to the total-contact cast. As they do not provide total contact, inflatable pads are used to improve contact. They are indicated in patients with impaired vascular circulation or in patients who require frequent removal of the cast for the treatment of concurrent ulcers

frequent removal of the cast for treatment of concurrent ulcers.

Keywords: Second metatarsal subluxation; pattern II neuro-osteoarthropathy

ACUTE NEURO-OSTEOARTHROPATHY: SANDERS AND FRYKBERG PATTERN II; DOUNIS TYPE II

A 54-year-old male patient with long-standing type 1 diabetes was referred to the orthopedic department because of mild pain, foot swelling and deformity, which developed 2 weeks after a foot sprain. He had a history of an intermediate amputation of the fifth metatarsal bone due to osteomyelitis resulting from a perforated ulcer on his fifth metatarsal head and metaphysis, which had occurred 2 years earlier.

On examination he had bounding feet pulses and severe diabetic neuropathy; the vibration perception threshold was above 50 V bilaterally. His left foot was painful, swollen and warm. A prominence on the dorsal aspect of his first metatarsophalangeal joint was visible and crepitus could be heard on passive foot flexion and extension. A radiograph revealed signs of acute neuro-osteoarthropathy involving the midfoot: osteolysis and fragmentation of the cuneiforms, tarsometatarsal joint involvement and dislocation of the first metatarsal joint (Figure 9.12). The patient was hospitalized and arthrodesis of the dislocated metatarsal bone was carried out by means of Steinmann pins (Figure 9.13). A non-weight-bearing total-contact cast was applied for 3 months, followed by 6 months in a weight-bearing total-contact cast. Two months later no major deformity was visible (Figure 9.14, immediately after cast removal).

As a rule, reconstructive surgery of neuro-osteoarthropathy is contraindicated in the acute dissolution phase (Eichenholtz stage I). The main reconstructive procedures carried out in patients with neuro-osteoarthropathy are osteotomy of a bony

Figure 9.12 Radiograph of acute neuro-osteoarthropathy involving the midfoot: osteolysis and fragmentation of the cuneiforms, tarsometatarsal joint involvement and dislocation of the first metatarsal joint are evident

Figure 9.13 Postoperative radiographs of the condition shown in Figure 9.12; fusion of the tarsometatarsophalangeal joints (arthrodesis) with the placement of Steinmann pins can be seen

Figure 9.14 Postoperative photograph of the patient whose condition is illustrated in Figures 9.12 and 9.13, 9 months after arthrodesis and use of a total-contact cast. No major foot deformity is seen

prominence and arthrodesis. When indicated, surgery is undertaken during the *reconstructive* stage (Eichenholtz stage III). During the acute phase surgery results in high rates of fixation failure, recurrent foot deformity and infection. Other contraindications to arthrodesis in such patients include soft tissue and bone infection, insufficient bone stock to achieve rigid fixation and non-compliance with postoperative regimens. However, in this patient arthrodesis in the acute phase was necessary, as major foot deformity and functional dysfunction was anticipated if the metatarsal head was left untreated. In addition, a prerequisite for successful arthrodesis is the presence of a sufficient bone stock for rigid fixation. If the operation had been postponed, this procedure might have been impossible as the cuneiforms and navicular bones were fragmented and collapsed. After the operation, patients with neuro-osteoarthropathy need long-term immobilization, irrespective of stage. In general, the immobilization period following an arthrodesis is double that required by patients without neuropathy.

Keywords: Acute pattern II neuro-osteoarthropathy; arthrodesis; reconstructive surgery; Steinmann pins

NEURO-OSTEO-ARTHROPATHY: SANDERS AND FRYKBERG PATTERNS II AND III; DOUNIS TYPE II: FRAGMENTATION OF THE CUBOID BONE

A 64-year-old female patient with long-standing type 2 diabetes attended the outpatient diabetic foot clinic because of redness, edema, swelling and mild pain on the dorsum of the right midfoot, which had been present for the previous 2 months. She did not report any trauma. The feet pulses were normal but she had severe diabetic neuropathy. A plain radiograph showed fragmentation of the cuboid bone, a pseudoarthrosis of an old fracture at the base of the fifth metatarsal and bone

Figure 9.15 Plain radiograph showing neuro-osteoarthropathy. Fragmentation of the cuboid, a pseudoarthrosis of an old fracture at the base of the fifth metatarsal and bone fragments at the talonavicular joint dorsally can be seen

fragments in the talonavicular joint dorsally (Figure 9.15). Neuro-osteoarthropathy was diagnosed, and the foot was put into a total-contact cast for 8 weeks. A fibrous union was present despite the absence of radiographic signs of healing of the fractured fifth metatarsal. The patient wore high-arched custom-made shoes. No further bone destruction was found during the next 6 months.

Keywords: Neuro-osteoarthropathy; patterns II and III; type II; cuboid fragmentation

NEURO-OSTEOARTHROPATHY: SANDERS AND FRYKBERG PATTERNS II AND III; DOUNIS TYPE II: COLLAPSED PLANTAR ARCH

A 56-year-old insulin-treated female patient with type 2 diabetes since the age of 45 years attended the outpatient diabetic foot clinic. She had background retinopathy — treated with laser — hypertension, diabetic nephropathy and dyslipidemia, as well as a left foot deformity which she had had since the age of 52 years. She was a heavy smoker. She had an ulcer on the outer aspect of her left foot which had developed when she was 53 years old and had started as a bulla following a trauma caused by her shoe.

On examination, a collapsed left midfoot and claw toe deformity were present. She had a painful irregular ulcer on the lateral aspect of her left foot with local edema, erythema and purulent discharge (Figure 9.16). A hemorrhagic callus was noted on the dorsum of her fifth left toe. Peripheral pulses were weak. The vibration perception threshold was over 50 V and she had reduced sensation of pain, light touch and temperature. Achilles tendon reflexes were absent.

Triplex ultrasonography of her leg arteries showed severe obstruction of her common femoral arteries on both sides. A methicillin-resistant *Staphylococcus aureus* was isolated from the base of the ulcer and the patient was treated with intramuscular teicoplanin and ciprofloxacin. The

Figure 9.16 Chronic neuro-osteoarthropathy with collapsed plantar arch and claw toe deformity. An irregular neuro-ischemic ulcer is present over the lateral aspect of the fifth metatarsal head with local edema, erythema and a sloughy bed superimposing osteomyelitis. A hemorrhagic callus is seen on the dorsum of the fifth left toe

patient was referred to the Vascular Surgery Department for bypass surgery. Appropriate footwear was prescribed and the ulcer healed in 3 months.

A plain radiograph revealed cuneiform fragmentation and disruption of the tarsometatarsal joint (Lisfranc's joint). Osteomyelitis of the head of the fifth metatarsal was also present (Figure 9.17). Calcification of the digital arteries was also noted, a common finding in patients with diabetes.

Adequate blood supply is a prerequisite for neuro-osteoarthropathy. In this patient, peripheral vascular disease occurred after neuro-osteoarthropathy.

Figure 9.17 Plain radiograph showing chronic neuro-osteoarthropathy in the patient whose foot is illustrated in Figure 9.16. Fragmentation of the cuneiforms and disruption at the tarsometatarsal joint (Lisfranc's joint) with osteomyelitis of the head of the fifth metatarsal and calcification of the digital arteries, a common finding in patients with diabetes, are all evident

Keywords: Neuro-ischemic ulcer; neuro-osteoarthropathy

NEURO-OSTEOARTHROPATHY: SANDERS AND FRYKBERG PATTERNS II AND III; DOUNIS TYPE II: MIDFOOT COLLAPSE

A lateral radiograph shows midfoot collapse (collapse of naviculocuneiform, talonavicular and calcaneocuboid joints) due to chronic neuro-osteoarthropathy of combined patterns II and III (Figure 9.18). In addition, localized bone resorption at the naviculocuneiform joints can be seen.

Osteotomy of protruding bone is recommended if recurrent ulceration occurs despite the use of custom-made shoes and insoles.

Keywords: Midfoot collapse; neuro-osteoarthropathy

NEURO-OSTEOARTHROPATHY: SANDERS AND FRYKBERG PATTERNS II AND III; DOUNIS TYPE II: ULCER OVER A BONY PROMINENCE

A 64-year-old insulin treated male patient with type 2 diabetes diagnosed at the age of 46 years and acceptable diabetes control (HBA_{1c}: 7.4%), was referred to the outpatient diabetic foot clinic for a chronic plantar ulcer on his left midfoot. The

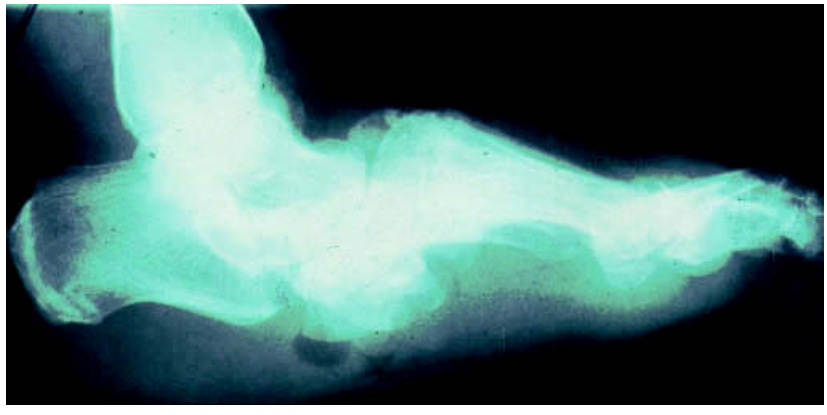

Figure 9.18 Plain radiograph of a midfoot collapse (collapse of naviculocuneiform, talonavicular and calcaneocuboid joints) due to chronic neuro-osteoarthropathy. Localized bone resorption at the naviculocuneiform joints is also seen

Figure 9.19 Chronic neuro-osteoarthropathy with collapsed midfoot, hallux valgus deformity and amputation of the second toe. Gross callus formation is seen at the borders of the neuropathic ulcer. Healthy granulating tissue can be seen on its bed

patient had background retinopathy, hypertension and diabetic nephropathy (proteinuria of 1.5 g/24 h).

One year earlier he had been hospitalized for almost 3 months because the ulcer was complicated by a severe deep tissue infection. During hospitalization he had extensive surgical debridement and was treated with intravenous antibiotics. A below-knee amputation was suggested, but the patient did not consent and he sustained a second toe amputation instead, due to osteomyelitis. The patient wore his usual shoes and refused the total-contact cast which had been suggested.

On examination, he had severe peripheral neuropathy (the vibration perception threshold was above 50 V bilaterally) and bounding peripheral pulses. He had chronic neuro-osteoarthropathy of his left foot. Hallux valgus deformity and a collapsed midfoot were observed. Bony prominences could be palpated at the base of the neuropathic ulcer (Figure 9.19).

An anteroposterior radiograph showed collapsed cuboid and navicular bones (Figure 9.19), extensive destruction and resorption of the cuneiforms with osteosclerotic changes and complete destruction of the tarsometatarsal, naviculocuneiform and talonavicular joints (Figures 9.20–9.22). Extensive resorption of the metatarsal diaphyses with a pencil-like appearance of the fifth metatarsal could be seen (Figure 9.21).

Debridement of the ulcer was carried out and the patient was advised to rest at home. Custom-made shoes were prescribed in order to offload the pressure from the ulcerated area and to accommodate the deformity. The ulcer healed in 12 weeks (Figure 9.23). Within the next 2 years the patient suffered two relapses of the foot ulcer at the same site.

In this case, chronic neuro-osteoarthropathy involves the Chopart's joint (talonavicular and/or calcaneocuboid) or naviculocuneiform joints, as well as Lisfranc's joint and, if left untreated, results in collapse of the midfoot and a rocker-bottom foot deformity. Recurrent foot ulceration at the apex of the collapsed bones is a common complication.

Keywords: Chronic neuro-osteoarthropathy; neuropathic ulcer

Figure 9.20 Plain radiograph of chronic neuro-osteoarthropathy in the patient whose foot is shown in Figure 9.19. Collapsed cuboid and navicular bones, extensive destruction and resorption of the cuneiforms and destruction of the talonavicular joint are evident

Figure 9.21 Plain radiograph of chronic neuro-osteoarthropathy in the patient whose foot is illustrated in Figures 9.19 and 9.20. Osteosclerotic changes and complete destruction of the tarsometatarsal and naviculocuneiform joints can be seen in addition to the pencil-like appearance of the fifth metatarsal

Figure 9.22 Plain radiograph of chronic neuro-osteoarthropathy in the patient whose foot is shown in Figures 9.19–9.21. Osteosclerotic changes and complete destruction of the tarsometatarsal joints together with bone resorption of the metatarsal shafts and osteophyte formation can be seen

ACUTE NEURO-OSTEOARTHROPATHY: SANDERS AND FRYKBERG PATTERN IV; DOUNIS TYPE IIIa

A 41-year-old male patient with type 1 diabetes diagnosed at the age of 19 years was referred to the orthopedic department of the hospital because of erythema and swelling of his right ankle, the onset of which had occurred rapidly some days earlier. No history of trauma was reported.

On examination, he had severe peripheral neuropathy and normal feet pulses. His right ankle was red, warm and swollen (Figure 9.24). A radiograph showed erosion

Figure 9.23 Healed ulcer in the patient whose foot is shown in Figures 9.19–9.22. Recurrent ulceration of the midsole in a patient with midfoot collapse is an indication of osteotomy in the protruding bones

Figure 9.24 Clinical presentation of acute neuro-osteoarthropathy of the right ankle which is red, warm and swollen

of the articular surfaces of the right tibia and talus. Bone fragments protruded medially (Figure 9.25). A diagnosis of acute neuro-osteoarthropathy was made and the patient was advised to rest, with his right foot in a total-contact cast. The cast was changed fortnightly for the first month and monthly for the next year. After this time osteoarthritic changes remained only in the affected joint and no major deformity was sustained.

Neuro-osteoarthropathy in the ankle is the third most common pattern of this condition (frequency of 13%) and may result in severe structural deformity and instability. An extensive period of immobilization is required in order to prevent deformities.

Keywords: Acute neuro-osteoarthropathy

Figure 9.25 Plain radiograph of chronic neuro-osteoarthropathy of the right ankle and foot as illustrated in Figure 9.24. There is erosion of the articular surfaces of the right tibia and talus and bone fragments protruding medially

NEURO-OSTEOARTHROPATHY: SANDERS AND FRYKBERG PATTERN IV; DOUNIS TYPE III (a, b, and c)

A 67-year-old patient with type 2 diabetes diagnosed at the age of 41 years attended the outpatient orthopedic clinic because of worsening painful ankle swelling after a strain in his right ankle 2 weeks previously. He had severe peripheral neuropathy and normal feet pulses.

A plain film showed resorption of the distal parts of the tibial and peroneal bones and involvement of the ankle joint (Figure 9.26). Pattern IV neuro-osteoarthropathy was diagnosed and the foot was placed in a total-contact cast and bed rest was advised. The patient did not comply with the advice and continued to be active while wearing the cast. One month later extensive resorption and fragmentation of the talus and resorption of the distal areas of the tibia and fibula was observed on a second radiograph. A bone fragment protruded posteriorly (Figure 9.27). Six months later a plain film showed extensive resorption of the talus, subchondral osteosclerosis of the tibia and calcaneus and extensive ligament ossification (the *reconstructive* stage of neuro-osteoarthropathy). Bone fragments protruded laterally (Figure 9.28). The patient admitted that during this time he had been active. He had significant

Figure 9.26 Plain radiograph showing acute neuro-osteoarthropathy. Resorption of the distal areas of the tibia and fibula and involvement of the ankle joint are evident

Figure 9.27 Plain radiograph showing progress of neuro-osteoarthropathy 1 month after the X-ray shown in Figure 9.25 was taken. There is extensive resorption and fragmentation of the talus and resorption of distal areas of the tibia and fibula and a bone fragment protrudes posteriorly

instability and varus foot deformity. Eventually the patient sustained a below-knee amputation.

A major problem in this pattern of neuro-osteoarthropathy is functional instability and foot deformity. Reconstructive

Figure 9.28 Plain radiograph showing progress of neuro-osteoarthropathy 6 months after the X-ray shown in Figure 9.27 was taken. There is extensive resorption of the talus, subchondral osteosclerosis of the tibia and calcaneus and extensive ligament ossification. Bone fragments can be seen to protrude laterally

procedures (such as arthrodesis) were not possible due to extensive bone absorption. With this type of articular destruction rehabilitation will be more successful if the patient uses a below-knee prosthesis rather than a patellar-tibial-bearing orthosis.

Keywords: Ankle neuro-osteoarthropathy; talus resorption; reconstructive stage

NEURO-OSTEOARTHROPATHY: SANDERS AND FRYKBERG PATTERN IV; DOUNIS TYPE IIIa

A type 2 diabetic female patient with bilateral chronic neuro-osteoarthropathy (in the *reconstructive* stage) resulting in marked bilateral varus foot deformity (Figures 9.29 and 9.30), attended the outpatient orthopedic clinic. She was unable to walk without crutches due to significant instability. On a plain radiograph complete destruction of the ankle joint and subchondral osteosclerosis at the distal ends of the tibia and fibula were seen, together with lateral resorption of the talus. Bone fragments were observed laterally in the ankle joint as were medial exuberant osteophytes (Figure 9.31). The patient underwent a realignment arthrodesis of the ankle joint by lateral ankle incisions and the ankle joint was fixed with a Huckstep nail (Figure 9.32). The postoperative results were excellent (Figure 9.33).

Significant deformity and instability is the main indication for arthrodesis in

Figure 9.29 Bilateral varus deformity of the feet due to chronic neuro-osteoarthropathy. Significant instability resulted in the patient's inability to walk without crutches

Figure 9.30 Lateral view of Figure 9.29

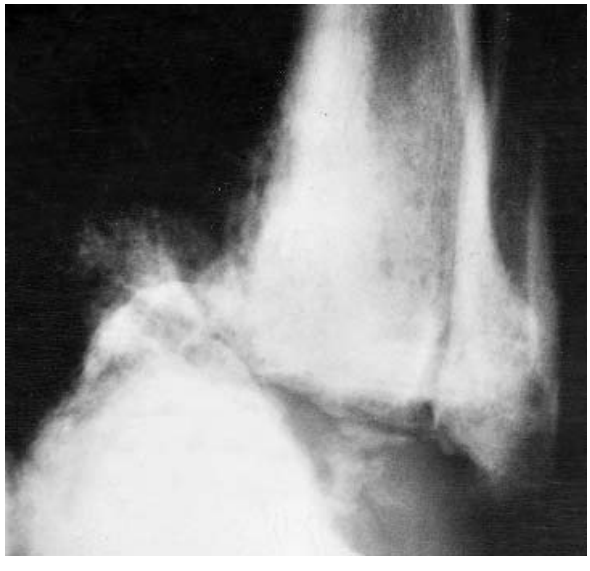

Figure 9.31 Plain radiograph of neuro-osteoarthropathy of the right foot of the patient whose feet are shown in Figures 9.29 and 9.30. There is complete destruction of the ankle joint, subchondral osteosclerosis in the distal areas of the tibia and fibula, together with lateral resorption of talus. Bone fragments are seen laterally in the ankle joint and exuberant osteophytes medially

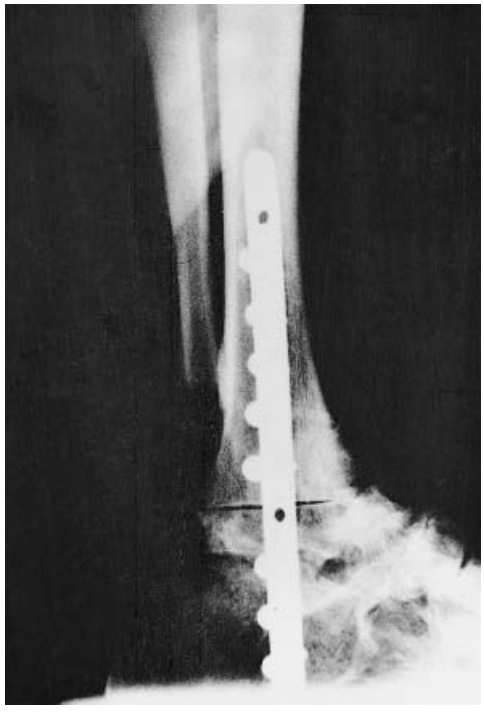

Figure 9.32 Plain postoperative radiograph of the right foot of the patient whose feet are illustrated in Figures 9.29–9.31. Arthrodesis of the ankle joint with the use of a Huckstep nail has been carried out

Figure 9.33 Postoperative photograph of the right foot of the patient whose feet are shown in Figures 9.29–9.32 after successful arthrodesis of the ankle joint

patients with neuro-osteoarthropathy. In experienced hands it is possible in almost 80% of cases to achieve the goal of a stable and shoeable foot after an arthrodesis in patients with neuro-osteoarthropathy. The use of modern techniques of internal fixation has significantly improved prognosis in these patients. The period of immobilization after an arthrodesis in patients with neuro-osteoarthropathy is prolonged, usually more than 4 months.

Keywords: Neuro-osteoarthropathy; arthrodesis; Huckstep nail

NEURO-OSTEOARTHROPATHY: SANDERS AND FRYKBERG PATTERNS IV AND V; DOUNIS TYPE III (a, b and c): INVOLVEMENT OF THE HINDFOOT

Chronic neuro-osteoarthropathy often leads to extensive resorption of the hindfoot (talus and calcaneus), navicular and cuboid bones (Figure 9.34). The patient whose

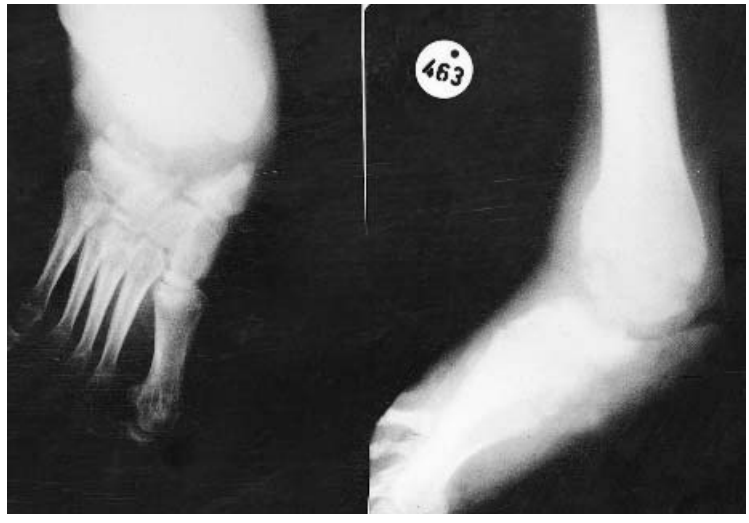

Figure 9.34 Plain radiograph showing chronic neuro-osteoarthropathy. Extensive resorption of the hindfoot (talus and calcaneus), navicular and cuboid bones is evident

X-ray is shown in Figure 9.34 is a 45-year-old female with long-standing type 1 diabetes who developed this complication after a severe ankle sprain. She suffered complete loss of sensation in her feet and symptomatic autonomic neuropathy (gastroparesis, diabetic diarrhea and orthostatic hypotension). Gait instability developed within 8 months, to the point where the patient was unable to walk without crutches. Although she used a total-contact cast, bone resorption was rapid and

Figure 9.35 Plain radiograph showing extensive resorption of most of the talus and calcaneus and of the distal end of the tibia–fibula in a patient with chronic neuro-osteoarthropathy. Osteolysis in the lower part of the calcaneus is due to osteomyelitis following a perforated ulcer

relentless, so that eventually the patient succumbed to a below-knee amputation.

Keywords: Chronic neuro-osteoarthropathy

NEURO-OSTEOARTHROPATHY: SANDERS AND FRYKBERG PATTERNS IV AND V; DOUNIS TYPE III (a, b and c)

Figure 9.35 shows extensive resorption of most of the talus and calcaneus, in addition to the distal end of the tibia–fibula in a patient with neuro-osteoarthropathy. The osteolysis in the lower part of the calcaneus is due to osteomyelitis. A chronic neuropathic heel ulcer is present, caused by a foreign body (Figure 9.36). Eventually the patient, who had long-standing diabetes and severe diabetic neuropathy, sustained a below-knee amputation.

Figure 9.36 Chronic neuro-osteoarthropathy. The osteomyelitis in the heel has been superimposed with a deep neuropathic ulcer in the patient whose X-rays are illustrated in Figure 9.35

Keywords: neuro-osteoarthropathy; heel ulcer; osteomyelitis

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